Visualising the Battlefield with Panoramic Displays

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Summary: This paper outlines ongoing research into the application of shared large screen displays (LSDs) for visualising the battlespace. This research was funded by the MOD's Corporate Research Programme 1999-2000 (TG5: Human Sciences and Synthetic Environments). Completeness and accuracy of information has the potential to enhance awareness of the situation and increases the probability of better decision making by the command team. Thus LSDs may lead to enhanced team situation awareness, and it is proposed that this in turn should lead to more effective decision making. The paper discusses panoramic displays in relation to the potential benefits that would arise when military command teams use them. Understanding of the command team's information requirements is crucial to the operational advantage gained with LSDs. This paper also reports the outcome of a user requirements capture exercise, where users were required to consider their potential information display requirements for an LSD to be used in 2010.

1 Introduction

The panoramic display is essentially a shared visual environment (with a display area of larger than 10 square feet) providing the operational teams with information on the status of assets. Applications of such displays can be as diverse as operational pictures presented to battlefield commanders, to trainers viewing trainees in multi-ship synthetic environments.

Large screen displays (LSDs) as a concept are not new. In the Second World War RAF controllers viewed a large desktop display of the air picture. There are also civil applications in safety critical environments such as nuclear power stations. However, recent advances in computing power have enabled digitisation of many aspects of the military environment. These include higher level requirements such as the presentation of the joint operational picture and specific vehicle-based concepts providing battlefield situational awareness and command. Nonetheless, the development of technology for large screen displays leaves the questions begging as to where the real military benefits are to be gained? In particular, in team environments, how can the LSD help improve operational decision making? Other important questions remain unanswered: how does the design of the LSD impact on Human Computer Interaction (HCI) and how can this be measured? The issues underlying these questions provided the framework for the project reported here. The objectives of the research are:

- To reach an understanding of the potential performance benefits of LSDs.
- To conduct empirical evaluations to develop optimal HCI techniques and formats for interfacing.
- To understand, at a conceptual level, changes to and benefits of team decision making with shared information space.

1.1 Background

Current and future military operations will depend chiefly on the C4ISR (Command, Control, Communications, Computing, Intelligence, Surveillance and Reconnaissance) framework. The force most likely to prevail in any operation is the one that accumulates intelligence faster and more accurately than its opposition. This involves the collection, dissemination, processing and interpretation of large volumes of information.

The current operational environment has resulted in:

- Equipment and missions becoming more complex.
- Risk of data overload.
- Team decision support.
- Tri-service and multinational missions and introduction of joint structure.

To support missions that are becoming increasingly complex, and thus requiring commanders/operations room personnel to act as

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information assimilators and overseers, information displays are being revolutionised. Further, as the likelihood of future missions being joint and/or multinational has increased, the joint tactical picture is of primary importance to mission controllers. Providing timely, accurate and relevant information means much of it may need to be filtered out to protect a commander from data deluge and facilitate his decision-making process.

Technologies such as liquid crystal displays (LCDs), back projection systems, large plasma displays, roll-up portable displays and 'picture window' flat screens are already being used in service or are in development. These will enable high resolution, integrated information displays to be presented on wide angle, panoramic displays simultaneously to a number of personnel. Moreover, the development of interactive technologies (such as shared virtual environments, smartboards and shared whiteboards) will enable operators to interact directly with the LSD using novel inputs (voice, eye, and touchscreen) over large distances.

Hence distributed command teams will become feasible. HCI issues are pertinent to such capabilities: who has the authority to interact with and change data is fundamental. Potential applications are vast and diverse. The command team could be in airborne command centres, on ships, or unmanned air vehicles (UAV) command stations. Battlefield displays could be presented with data fused information on one single, splayed, panoramic screen, which all individual(s) could view; potentially facilitating shared mental models, situation assessment and decision making. This project focused on an LSD application relevant to the three services and joint operations, that is the presentation of battlefield information to the command team. It is envisaged that this particular use of LSDs will have considerable relevance to current procurements and provide generic guidelines for other applications.

1.2 Guidelines for Panoramic Displays

Little is understood of how LSDs improve operator performance and knowledge of the related human factors issues is minimal. For example, most of the existing HCI research is related to standard individual workstations. There are few recommendations for how interfaces on LSDs should be designed, and how LSDs should be integrated within the user's operational environment and task structure. McLeod [1] recommends that LSDs are potentially suitable to support team working when one or more of the following conditions are met:

- Operators require concurrent use of information/displays
- Operators have shared tasks
- There are non-conflicting task needs
- Operators have common information needs
- Feedback is required to be given to whole teams
- Operator tasks require a common frame of reference (i.e. an indication of where an operator is within the big picture, to supply overall context, and/or help prioritise an individual's operation)
- Operator tasks require high-level summary/overview information.

Further definitions of the HCI requirements for interacting with LSDs are scarce. There are three main categories of human factors design requirements relating to physical properties, information display requirements and workspace requirements that must be met to optimise performance when using LSDs:

- Physical display requirements include full colour capability, sufficient viewing angle, high resolution and uniform light distribution.
- Information display requirements include the need for a lack of clutter on the display and the need for critical information not to be altered or deleted accidentally.
- Workspace requirements mean that panoramic displays should be functionally consistent with the physical room layout and integrated with command post positions and roles. Operators must also be familiar with using LSDs.

Finally, how LSDs are applied to the team environment is critical. Stubler and O'Hara [2] generated several guidelines to be applied to the use of shared LSDs in order to enhance team performance, which were grouped into the following four sets of functions:

- *Provide a status overview*: to support high level decision making and enhance team memory, where operators are performing multiple concurrent tasks.
- *Direct staff to additional information*: by posting critical information to update individuals' knowledge states.
- *Aid co-ordination of team activities*: to facilitate team identity and clearly communicate common tasks, where

multiple tasks and proceduralised performance are present.
- *Support collaboration among team members*: by acting as a focal point for team discussions.

It is thus possible that the use of panoramic displays may enhance team performance in a military Command and Control (C2) environment. This leads to the important issue of how panoramic displays will impact on team processes within the command team. Understanding team processes and models is crucial in understanding and exploiting the effect that panoramic displays may have on team performance and processes in a military command setting.

1.3 Panoramic Displays in the command centre

LSDs have been used for several years in a range of civil command centre applications, such as power industries (nuclear and electricity) and transport systems (rail and air), where monitoring of the status of safety-critical systems is essential. These displays are used mainly in normal operations, but need to support decision making in emergencies. As the information portrayed is often complex, these LSDs enable the overseer to trace an event back to its source. In contrast, the military LSDs will need to maintain rapidly changing, unpredictable and conflicting information with safety still being a concern, but mission success being the overriding factor. It is how LSDs will impact on team performance and team processes (e.g. intra-team communication) in a military environment that is little understood [3].

The use of LSDs is likely to have an affect on the following main aspects of team processes: communications, leadership, situation awareness, shared mental models, decision making, workload management, mission analysis, planning and adaptability, and teamwork.

Recent studies that concentrated on realistic scenarios in a military setting, showed that teams do tend to perform better when working with shared LSDs. For example, Hiniker and Entin found that shared battle graphics presented on a large overhead screen seemed to increase the effectiveness of teams by providing more accurate information concerning a wider overview of the situation. In a subsequent experiment [4], participants reported that understanding crisis situation and communicating knowledge of the situation was easier and better with the use of LSDs.

Hiniker [5] has discussed in depth the use of a Common Operational Picture (COP). The COP is an annotated electronic map of the battlefield, showing the location of own and enemy forces. The COP updates rapidly, allowing commanders to visualise the situation and hypothesise possible courses of action. Wentz [6] reported the use of the COP in Bosnia in 1998. It was found to be useful, but better integration between pictures was felt to be necessary.

Nonetheless despite the expected benefits of LSDs, there are few studies identifying user requirements or describing empirical evidence to support the anticipated benefits. The intention of this paper is to outline the knowledge elicitation phase of this research project that feeds into the prototype battlefield LSD, which is being developed as part of this project.

In parallel with this knowledge elicitation phase a communication analysis of a simulated command team exercise was carried out. This is reported in detail in [7]. As Table 1 illustrates, the most common type of communication was providing situation updates (18.9% of the total number of communications), followed by requests for information (15.3%) and providing information on request (14.7%). It was important that these requirements were met in the design phase.

2 Knowledge elicitation

The objective of this phase of the project was to understand how LSDs could provide decision support from the command team perspective. In order to meet this objective two command teams were selected as potential users of LSD technology and knowledge elicitation techniques were utilised to identify their requirements. This involves:

- Understanding the users' HCI requirements
  - Focus groups with two command teams were conducted to identify command team information needs
- Encapsulating their needs
  - Trials to assess cognitive benefits will follow on from the identification phase assessing command performance.

As a consequence of the increasing emphasis on joint operations, the first end-user team was drawn from Operations Team Staff in the UK Permanent Joint HQ (PJHQ) representing joint operational and strategic crisis management. The

second command team represented the single-service viewpoint, in this case staff from the Combat Operations team at the UK Combined Air Operations Centre (CAOC).

In order to identify key applications for LSDs, two methods were utilised with Subject Matter Experts (SMEs). These were cognitive walkthroughs and focus groups. Focus groups are a direct and qualitative research approach, often in the form of an interview conducted by a trained moderator among a small group of experienced respondents in a natural manner [7]. This is all done in order to gain an insight into the group subject, through instilling a relaxed, informal atmosphere that encourages spontaneous comments.

Cognitive walkthrough is a technique based on cognitive theory for evaluating the design of a user interface, it attempts to elicit information on how well the interface supports 'exploratory learning'. Cognitive walkthroughs aim to evaluate four aspects; the user's goal, the accessibility of the correct control, the quality of the match between the control's label and the goal, and the feedback provided after the control is acted on. This method is often used in the early stages of design, before empirical user testing is possible. The method involves several approaches ranging from heavily structured questionnaires to more informal but structured group sessions. Such groups are normally composed of the interface designer and a group of his or her peers. One of the group takes the role of 'scribe' (recording the results) and another takes the role of 'facilitator' (keeping the evaluation moving) [7].

As the aim of the PJHQ and CAOC visits was to capture information on military command teams' concepts of LSDs, capturing these concepts required a flexible method. After considering the qualities of both focus groups and cognitive walkthrough, it was decided that the exercise used for both PJHQ and CAOC would be an informally structured group session. This was aimed at evoking a relaxed atmosphere that would capture both answers to set questions and spontaneous comments [7].

During each exercise, the command teams were asked to identify potential uses of LSDs in 2010 and then were asked to prioritise information that could be displayed to the team. Following on from this understanding of how LSD information could support team situational awareness, the SMEs were asked to design a prototype LSD. Finally, in the case of the single service staff, there was a walkthrough of a possible scenario to confirm the layout and utility of the LSD.

3 Results

3.1 Single service LSD

This exercise was designed to capture operational staff views on how LSDs could support the command team in air combat operations. It was also aimed at identifying how critical information should be displayed to and interfaced with by the team. While it was not the intention to derive particular screen layouts, a default screen layout was identified as part of the group activity (Figure 1).

As a result of these exercises, the following two applications of LSDs were evident: briefing and team situational awareness. In particular, the LSD would benefit staff shift changes and maintain team awareness of events that they were not party to at their own consoles. The commander commented that the LSD made a good focus for team attention during briefings.

Displaying weather information was an important LSD requirement. This was viewed as an important factor for hand-over briefings, predictions and continual reference during operations. As with all the information displayed, it was suggested that such a display should be totally flexible and able to be applied to any situation.

Unlike the joint team exercises, the single service operational team did not view news feeds and video conferencing as essential. The team suggested that the prime information source for the LSD should be exactly what the Chief of Combat Operations (CCO) desires on the screen at any particular time. Interaction should be mainly through the CCO, although others should be able to take over and manipulate the LSD as necessary, e.g. when briefing. It is useful within a scenario for each member of the Operations team to be able to brief in turn, using the LSD where necessary to update all team members' situational awareness. This raised the issue of live bulletin boards. The team suggested that such a concept would prove to be a useful tool. The idea behind a 'bulletin board' would be a common area where any one of the Combat Operations team could project information onto the LSD, thereby attracting the shared attention of the team to important information. In addition it was suggested that the screen should have a 'zoom' function that would allow any relevant information to be selected from the screen and be re-sized as required.

As a final product of the exercise, a default screen layout for an LSD with suggested functionality was proposed (Figure 1). It was felt essential that all windows were moveable and re-sizeable. The interface should be controlled by the CCO (except for the bulletin window). All team members should have access to a remote mouse for giving briefings, enabling them to highlight/manipulate windows of interest. Further, the team should be able to record all actions, so they could review events and save useful configurations for later use.

3.2 Joint LSD

A similar exercise and discussions were conducted with the joint team operating at strategic/operational level. The following summarises user requirements:

- The interface should utilise current computer formats, for example the use of windows, drop down menus and icons.
- All screen formats should be reconfigurable.
- Users should have the ability to move between levels of information at the click of a button; for example view a map at different resolutions.

As the joint operations team controls a number of operations simultaneously, the LSD must have the ability to display the information for a number of operations at the same time. The background of each section of the display was the respective operational picture. Extra information required for the task from a range of sources including video, imagery, newsfeeds, video conferencing, briefings, etc. can also be displayed (see Figure 2).

Furthermore, when required, it may be necessary to promote one of these operational areas to fill the entire LSD with the remaining operations being minimised. It was also important that the LSD reflected the control room layout and operating functions.

In addition to team situational awareness, the LSD would be used to brief important visitors. The joint team was often in the position where they are required to display information centrally. Therefore there is a requirement for the whole screen to become a dedicated briefing facility.

It was clear that from the joint perspective there was a strong user requirement for an LSD and support for a flexible, versatile system.

4 Generic HCI guidelines for LSDs

As a result of the exercises investigating optimal LSD format, involving joint and single service staff, three general categories of recommendations for display design have become clear. These fall under the headings of: display configuration, interaction procedures and user group considerations.

4.1 Display configuration

A large screen display should:

- Be flexible and re-configurable to the needs of different user teams and their composition.
- Have the ability to move, re-size and overlay any information sources onto and over any area of the LSD.
- Have the ability to zoom in or out of any area on the main display.
- Display information at its highest level; plans and workings are not recommended for display (unless the tasks of the team demand it).
- Make the best use of the available space in any section of the display.

4.2 Interaction procedures

- LSDs must be simple and straightforward to operate.
- LSDs must conform to population stereotypes (i.e. user expectations about how the system will work).
- Access to and exit from any LSD systems should be via one procedure (e.g. one click of a mouse button).
- There needs to be a process whereby useful layouts and/or settings can be saved.
- Movement between different levels of information should be at the click of a button.
- The LSD should provide an 'on-line' help procedure.
- The LSD should have a system that runs hand-in-hand with a time-line of significant

events. Therefore providing traceability of all decisions.

4.2 User group considerations

- LSDs must be designed around how the user team works, rather than dictating how the user team works.

- LSDs must support communication. This can be achieved by matching the needs of the team with the information that is displayed on the LSD to support intra-team communication.

- Interaction with the LSD should be primarily through the CCO, however any member of the command team should have the ability to manipulate the LSD for briefing purposes via a single, communal remote mouse.

- It is essential not to design out the role of the individual. LSDs should be used to increase situational awareness for all team members and allow for individuals to carry out individual tasks independently.

- There should be the provision of two types of LSD, a fixed version and a deployable version. The deployable LSD version should be portable, robust and reliable. Both versions should be functionally similar to avoid the need for additional training.

5 Conclusions

The changing nature of world security has dictated the requirement for flexible and deployable forces. Some of the impacts of the security environment and technology progress on military operations have been reductions in crew levels, interest in remote control of systems, e.g. Unmanned Air Vehicles (UAVs), and the need for complex command and control structures. The philosophy of developing an interface that allows team members to develop an accurate mental model of the location, activity and performance of assets may be a key component in minimising the risk of operator error due to an incomplete/incorrect awareness of the operational situation. The introduction of LSDs will have the potential military benefit of allowing the commander and command team to share information space, potentially enhancing situational awareness and team decision making.

Nonetheless, there are many unknowns in assessing the potential operational benefit of LSDs, both in terms of the optimal HCI, and methods to assess team performance benefits. As a result of this research, there is a greater understanding of how operational pictures are currently used and how future LSDs can be designed to optimise command team performance. This report has identified LSD HCI requirements for operational tasks that can be used in future designs.

6 Acknowledgements

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Communication type	Number	Percentage of total communication
Providing situation updates	240	18.9
Requesting information	194	15.3
Providing information on request	186	14.7
Providing information without being asked	104	8.2
Commands/orders	102	8.1
Questions/enquiries	91	7.2
Seeking clarification	74	5.8
Acknowledge/verify/confirm	47	3.7
Observations	40	3.2
Providing assistance/backup	38	3.0
Guidance/suggestions	34	2.7
Providing clarification	32	2.5
Requesting backup/assistance	21	1.7
Repeating information	20	1.6
Stating priorities	17	1.3
Social/other	13	1.0
Giving feedback	5	0.4
Prompts	4	0.3
Error correction	3	0.2
Agreement	2	0.2

Table 1: Communication types in frequency order

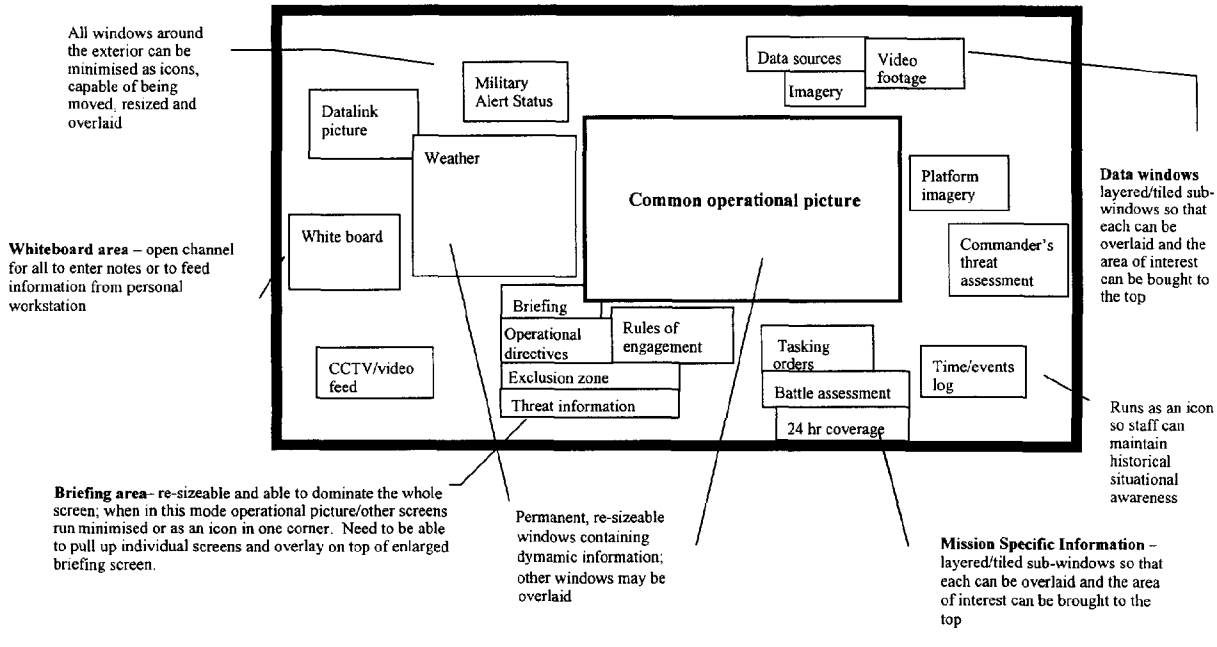
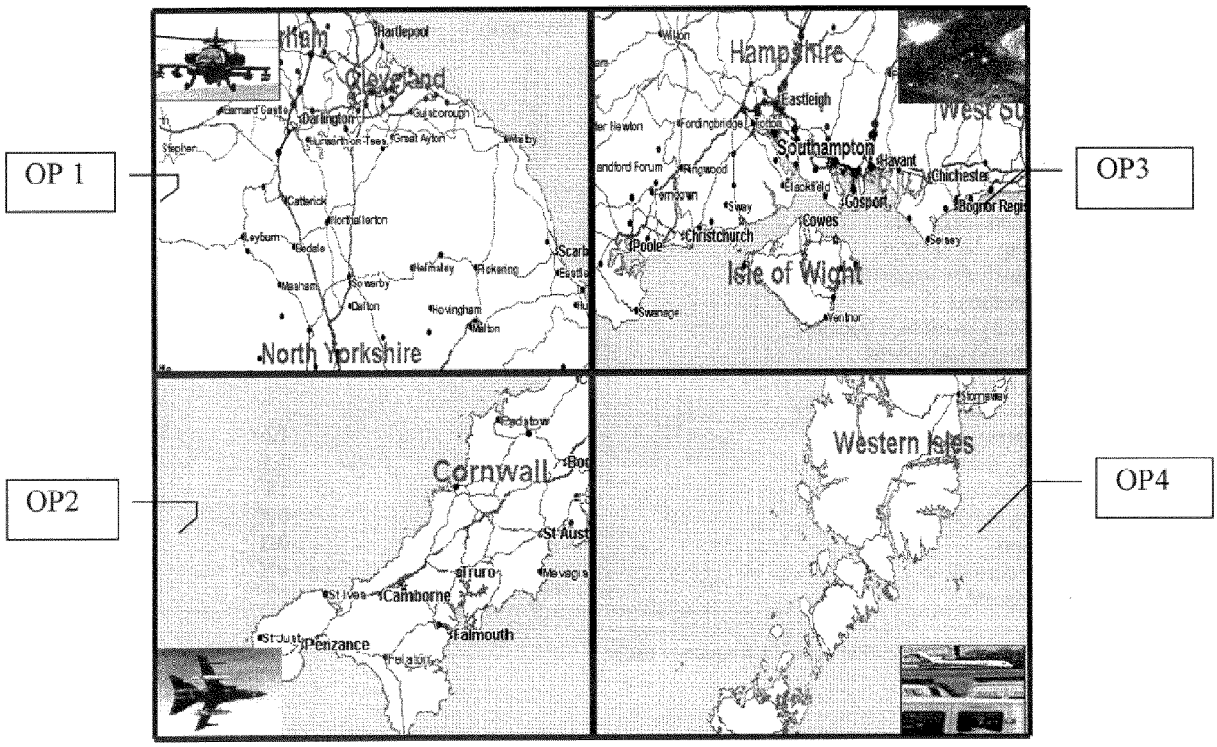


Figure 1: Generic single service LSD layout



*(The operational boxes OP1, 2, 3 & 4 represent which operation each quadrant will be displaying and will not appear on the LSD.)

Figure 2: Joint services LSD screen layout (for four operations).

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